Investigation and Optimization of Miniature Fan-Based Impactors

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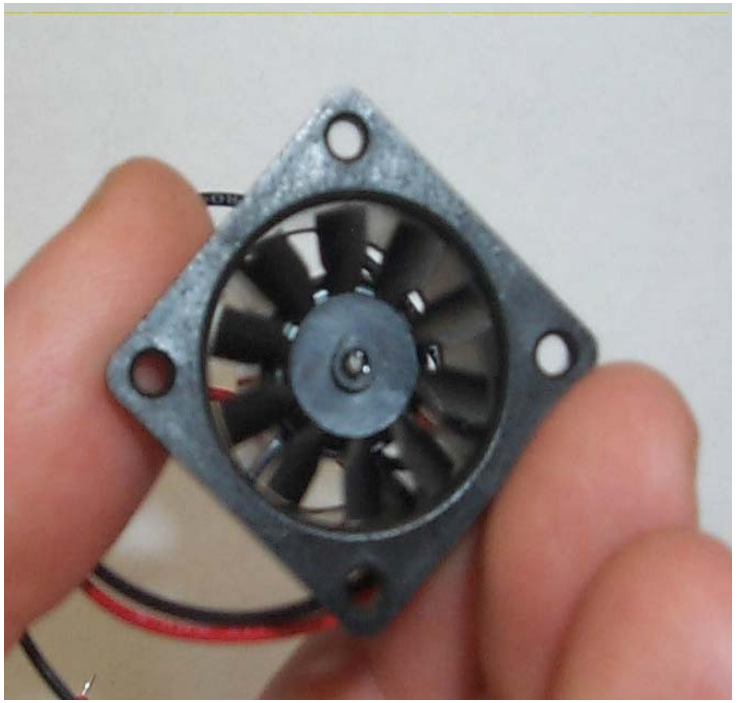
Background

- Collectors are an important component of a biodetection system to concentrate biological particles for detection
- Need a small and low power option to interface with increasingly smaller biosensors
- Other desirable features for biocollector design:
  - High collection efficiency in the 1 – 10 micron range
  - High sample volume
  - Inexpensive, disposable
  - Simple operation
  - Simple recovery

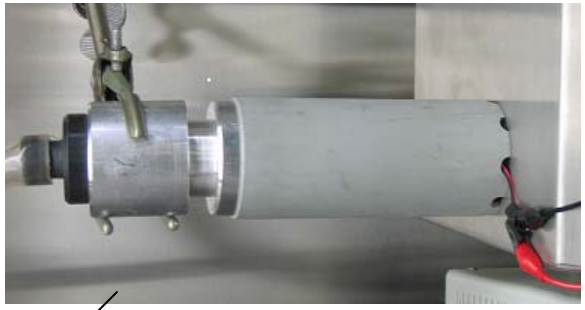
Fan-Based Impactor

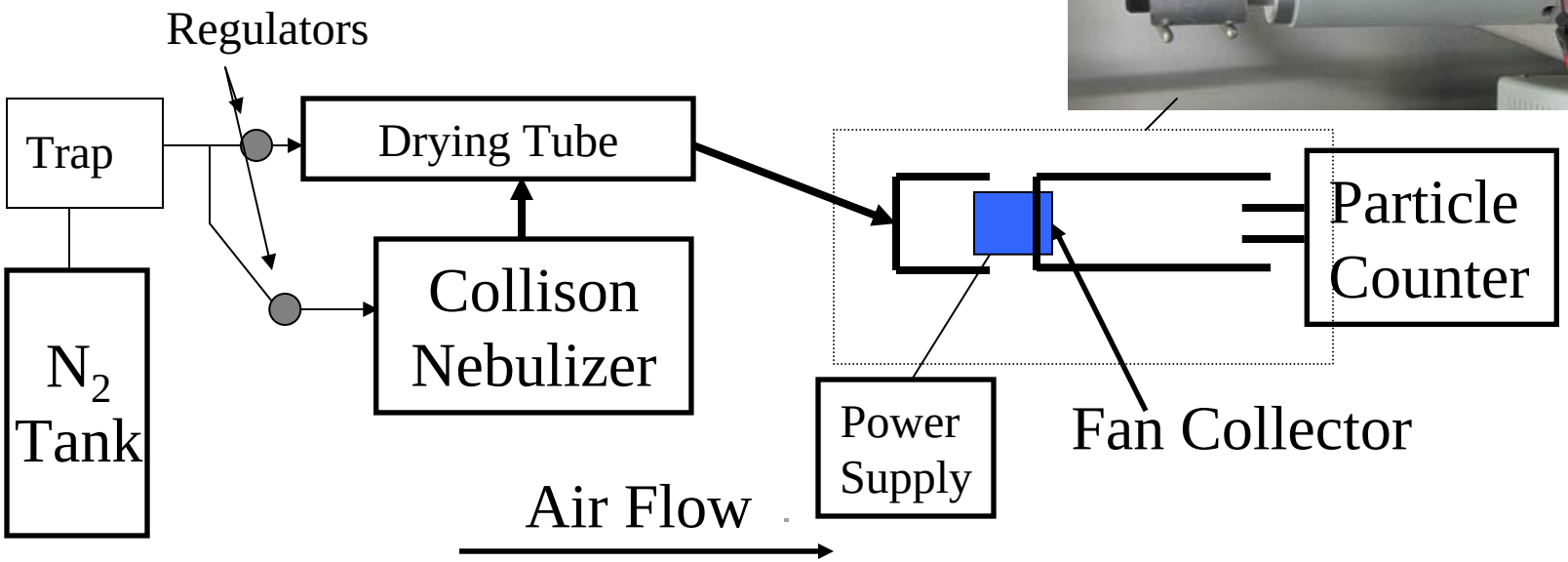
Example Fan Specification:	
Weight	15 – 34g
Rated Voltage	6 – 12V
Imax	600 mA
Power	0.2-9W
FR l/min	100 L/min
MTTF	up to 4000 hrs
T/^{o}C	-20 to + 65



A high flow vane-axial fan utilized as an impactor provides many desirable biocollector features.

Testbed Design

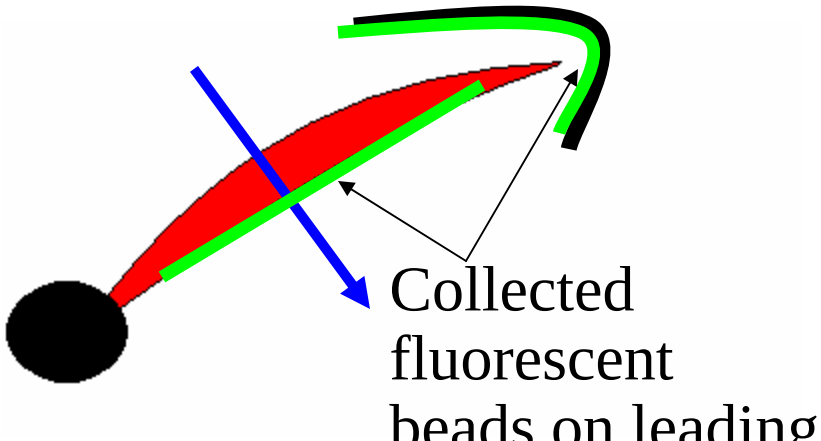




- Test particles – 1.0 micron polystyrene latex spheres
- Flow rate of system – 120 LPM
- Met One 3315 Airborne Particle Counter with seven bin sizes (range 0.5 – 25 microns) – monitor bin 1.0 – 2.0 μm
- Collection efficiency calculated by measuring particles not collected
- % Collection Efficiency = $[(C_o - C_{fan})/C_o]*100$;
- C_o = baseline particle count and C_{fan} = particles that pass through the fan

Mechanism of Fan Collection

Direction of Particle Motion



Collected fluorescent beads on leading edge of blade and fan rim

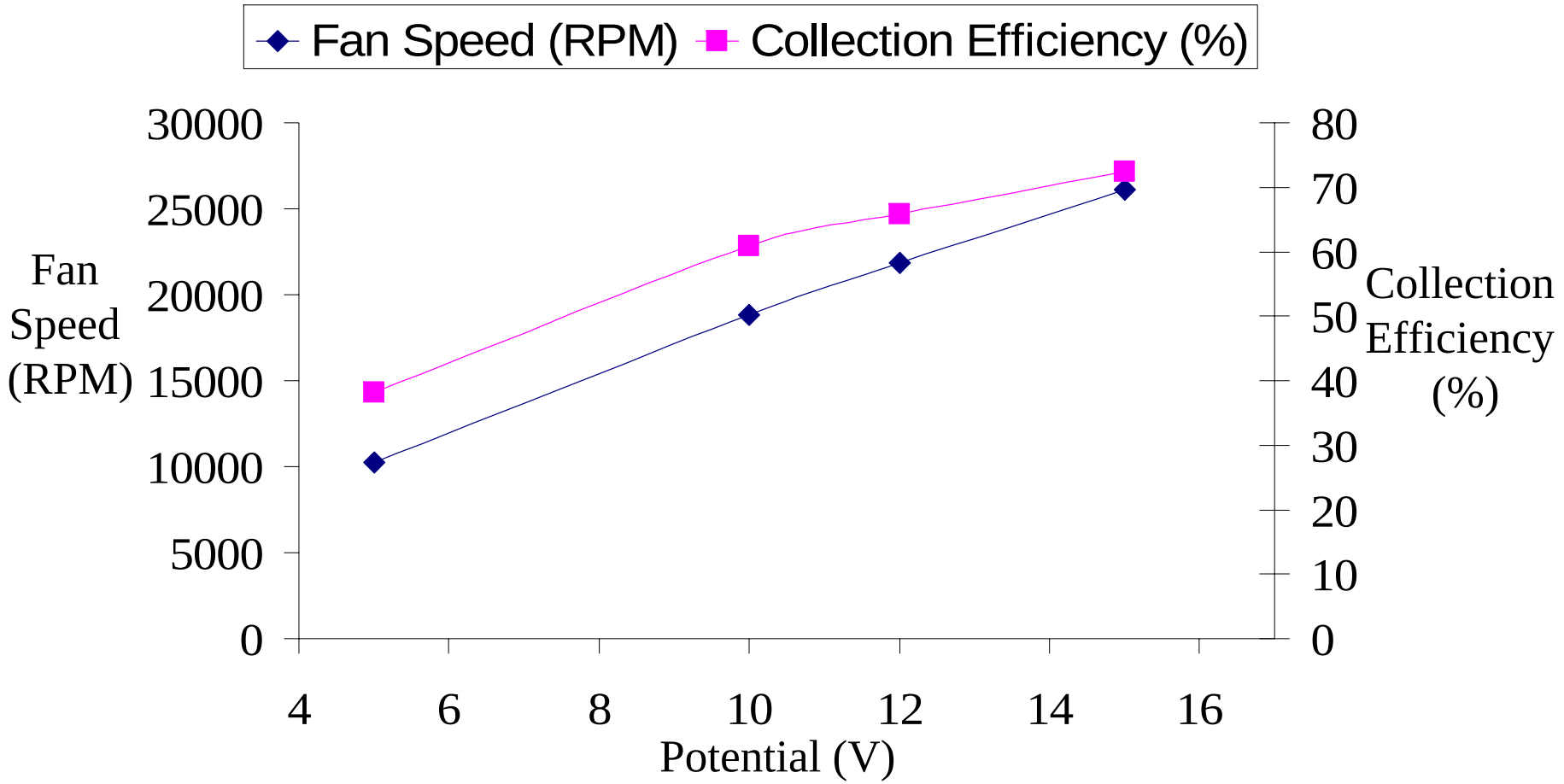
Fan showing fluorescent PS

Impaction on the fan blades and rim is the mechanism of collection.

Collection Efficiency Experiments
Polystyrene Latex Spheres

- Single fan with rated voltage of 12V
- Fan washed with isopropanol and allowed to dry in a flow bench to minimize dust particles
- 67 + 2% collection efficiency at 12V
- 72 $\pm$ 3% maximum collection efficiency achieved by overdriving to 15V

Effect of Fan Speed on Particle Collection



An increase in applied voltage increases the fan speed which leads to improved collection efficiency.

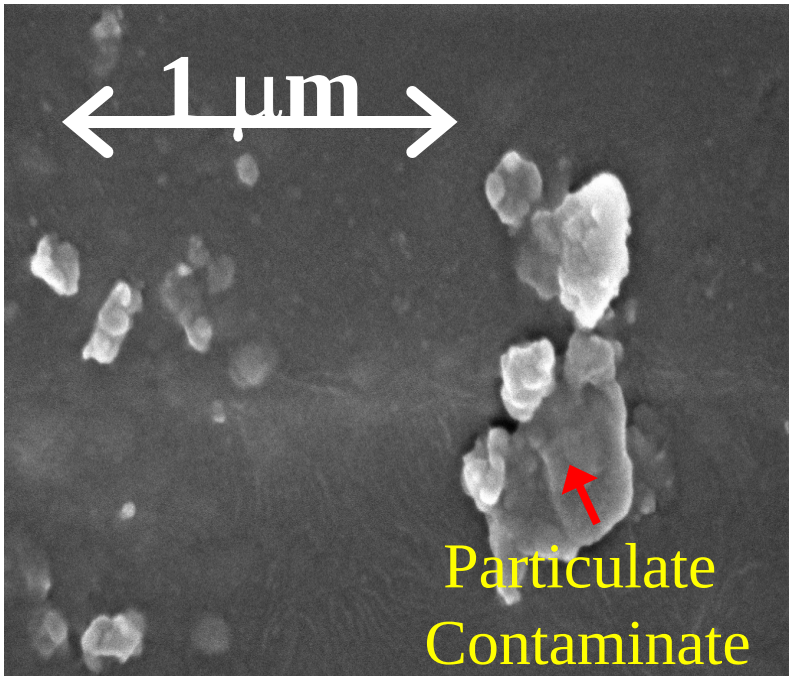
Preliminary Collection Experiments with BG Spores

The RAPID PCR

- Collection efficiency of greater than 80% for 1μm BG spores (with Jay Eversole and Cathy Scotto, Code 5611 at NRL)
- 500 μl water used to process the polystyrene beads and BG spores off the fans
- Recovery and detection of BG spores confirmed with RAPID PCR system

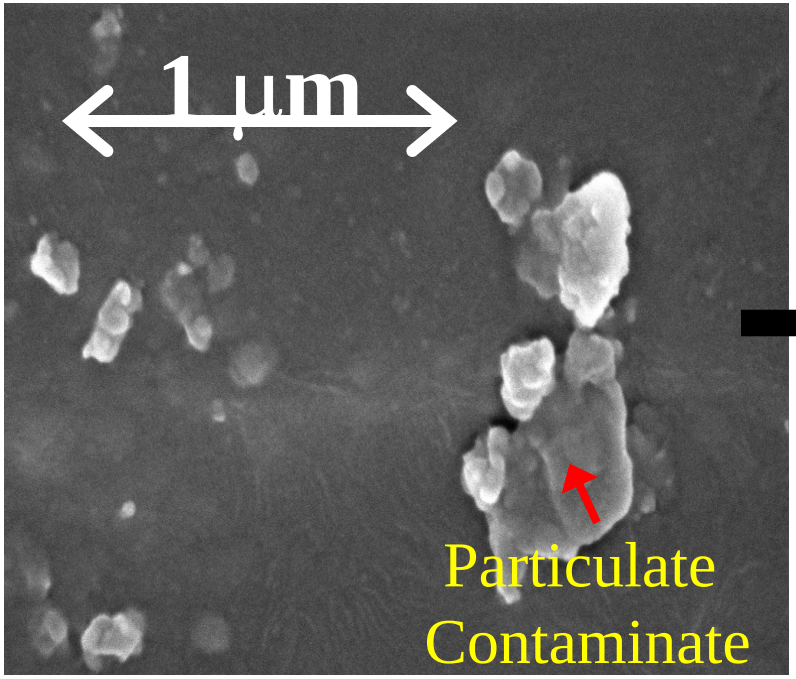
Surface Modification Effects on Collection Efficiency

- As received, fan surface is a dense smooth collection substrate
- Modify fan surface to change surface area and energy
- Modifications: surface roughening, Al_2O_3, Ti

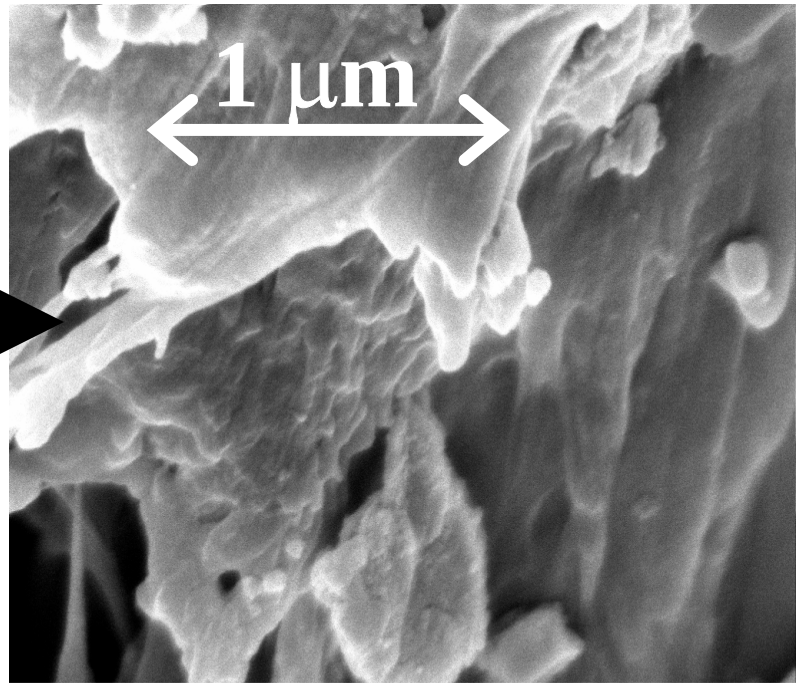


SEM image of standard fan blade surface

Surface Modification: Sand Blasted Collectors



SEM image of standard fan blade surface

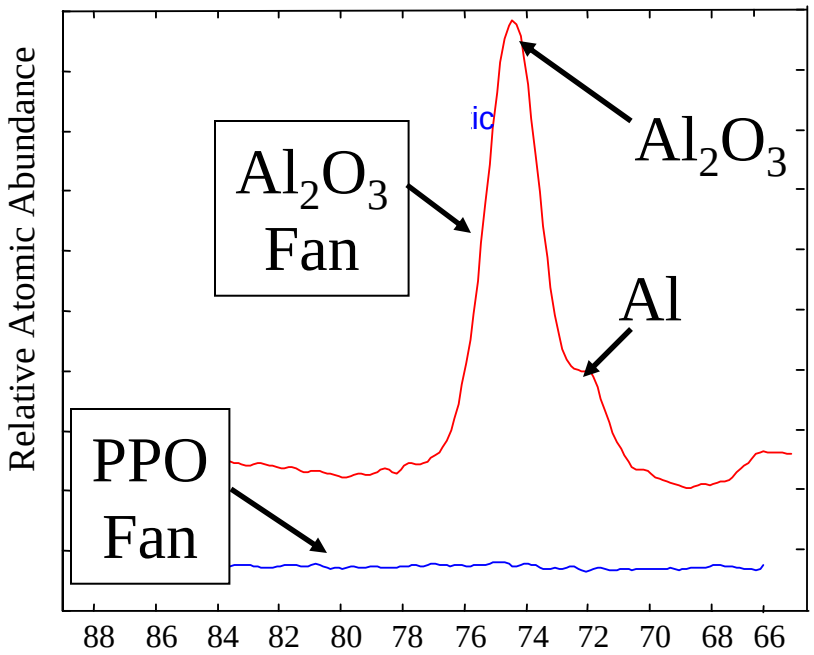


SEM image of sand blasted PPO fan blade

- Preliminary experiments show 0 – 20% improvement
- Need more rigorous control of surface roughening

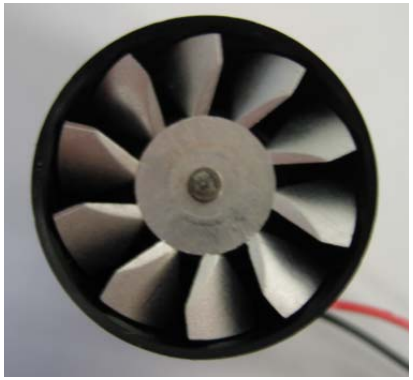
Surface Modification: Al_2O_3 and Ti Coated Collectors

- CVD used to grow aluminum oxide film directly on to PPO impellers
- XPS used to verify the oxide layer
- Titanium films were also investigated



XPS of aluminum oxide fan

Al_2O_3 coated fan



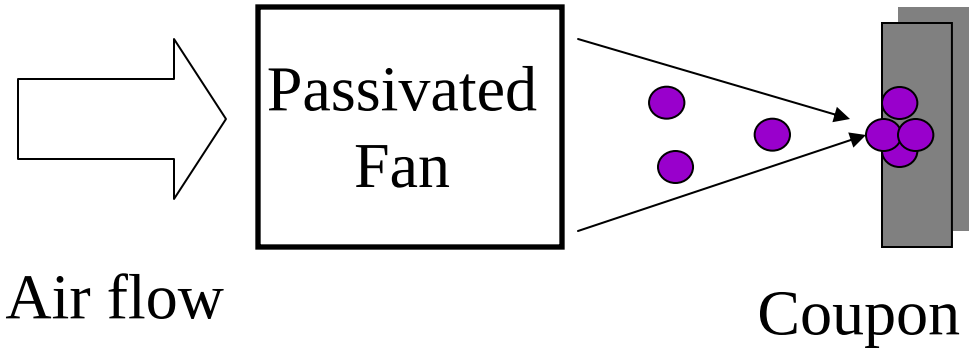
Comparison of PPO, Al_2O_3 and Ti Collectors

Collection Efficiency (%) at 10,000 RPM		
PPO	Al_2O_3	Ti
37 ± 6	36 ± 1	32 ± 6

- All the surfaces have the same collection efficiency within the error

- Due to high flow rates, the particles have high linear velocity and all surfaces appear the same

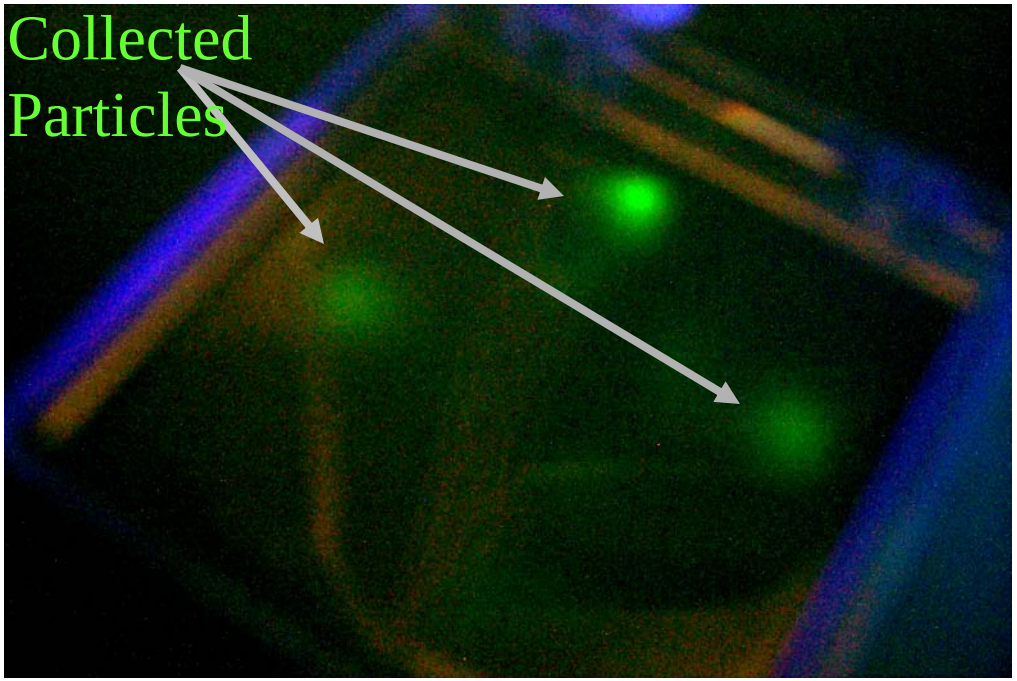
Coupon Impactor Design



- Fan used as impeller instead of impactor
- Decrease impact force for improved collection and less re-bounce with softer surface
- Concentrate particles in smaller footprint area for ease of recovery or analysis
- In some cases may be able to culture directly on coupon

Coupon Collector Proof-of-Concept Experiment

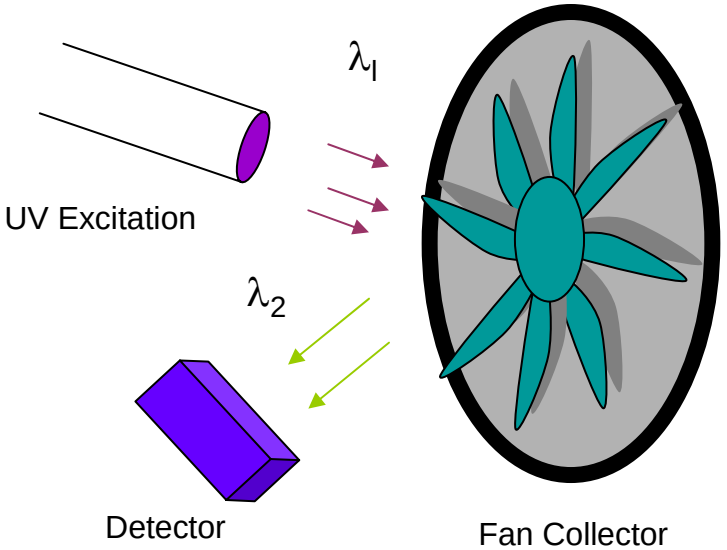
- One micron fluorescent PSLs collected on coupon aft of the fan exhaust
- Four areas of collection because of geometry of fan



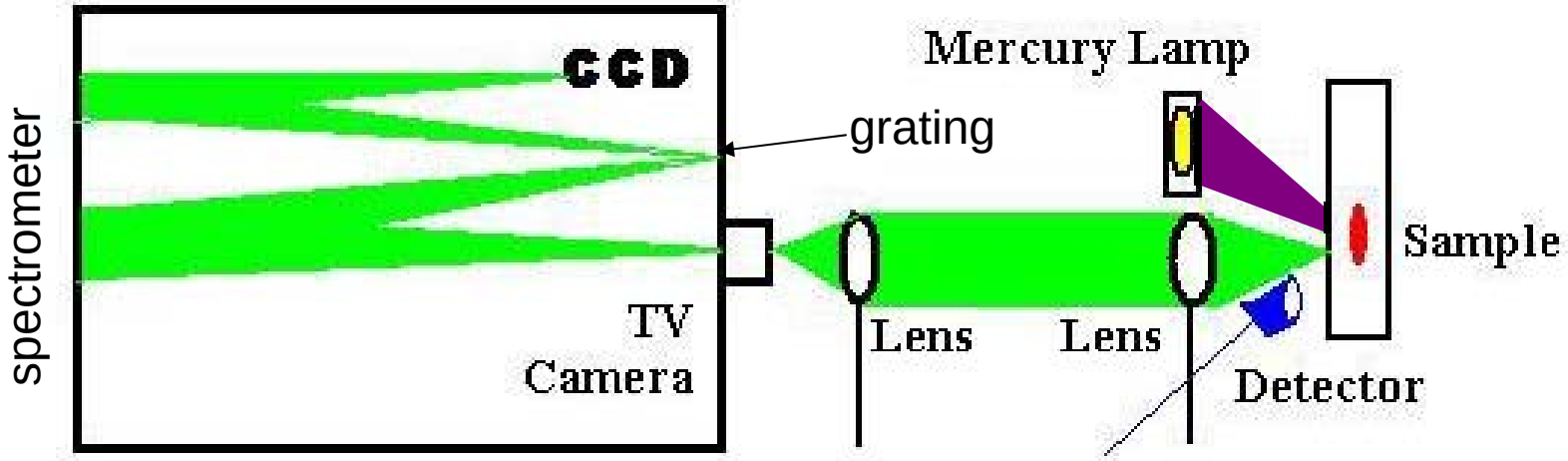
One micron fluorescent PSL spheres collected on planar coupon illuminated using a 245nm lamp

Simple Fan Biotrigger

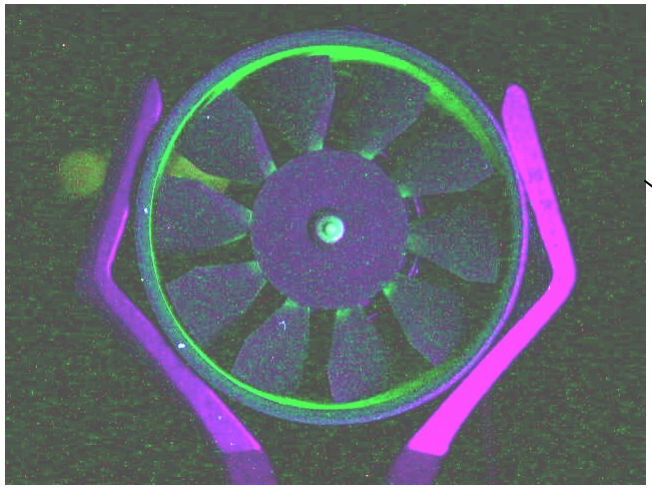
Concept

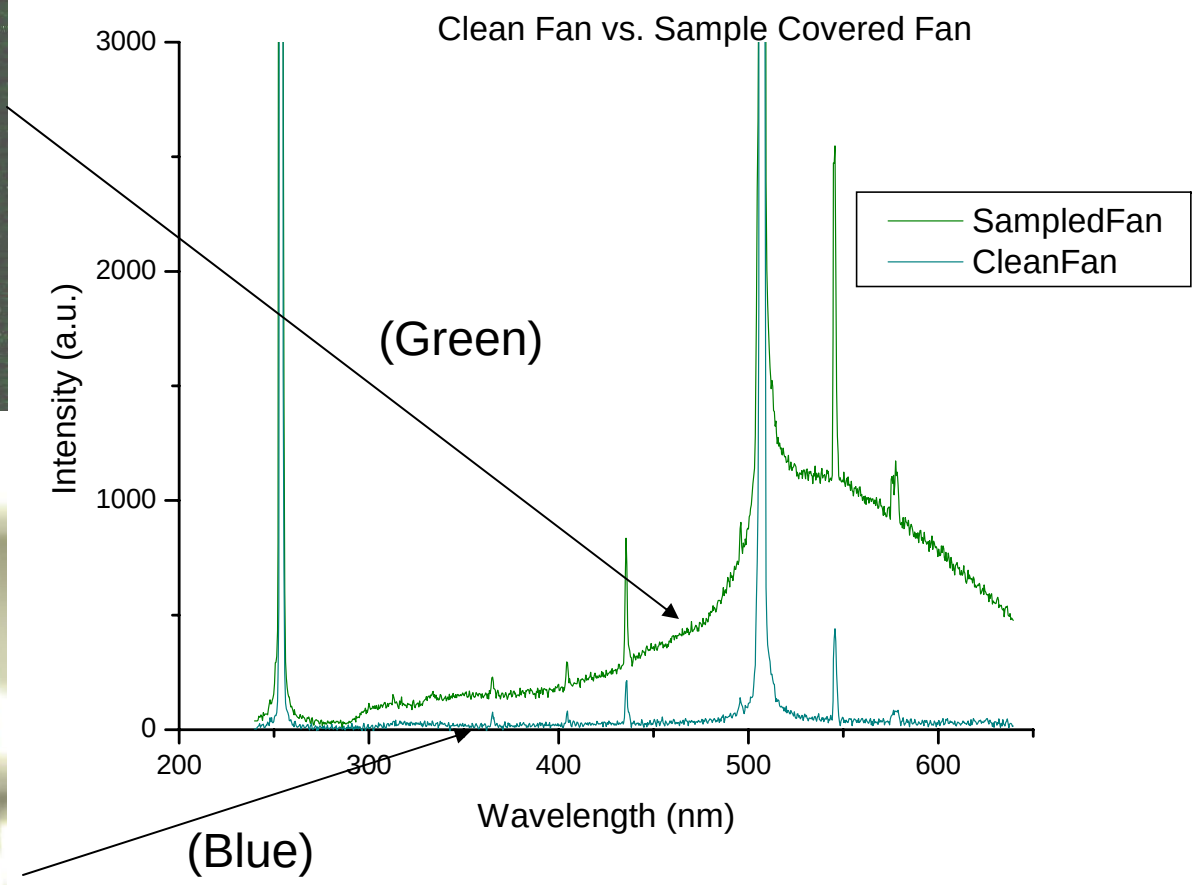


Experimental Design



Fan Biotrigger Proof of Concept





Conclusions

- Fan-based impactor can be used as a low power, small, disposable biocollector.
- Collection efficiencies of >70% have been demonstrated for PSLs and BG spores.
- Increasing fan speed increases collection efficiency while surface material has little effect.
- Coupon collection shows promise as a secondary route to low power, higher efficiency collector.
- Low cost biotrigger is possible with fan coupled to inexpensive light source and detector.

Future Directions

- Optimize collection efficiency by examining variables
  - blade pitch
  - surface roughening
  - surface materials: softer surfaces
- Further investigate coupon collection to characterize and optimize collection efficiency
- Investigate viability

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